

BASIN-SCALE OCEAN PREDICTION SYSTEM

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LONG-TERM GOALS

An eddy-resolving nowcast/forecast system for the North Pacific basin using the 1/16 degree Pacific basin NRL Layered Ocean Model (NLOM). This system will include assimilation of satellite altimetry into the eddy-resolving NLOM which will provide the accurate sea surface height fields to produce 3-D volumes of temperature, salinity, and sound speed using the synthetic data bases of MODAS 2.0.

OBJECTIVES

This project is a coordinated 6.2 and 6.4 effort to develop an eddy-resolving nowcast/forecast system for the North Pacific basin and ultimately the global ocean. Ocean prediction (hindcasting, nowcasting, and forecasting), as opposed to ocean simulation, requires ocean observations. Ocean models forced by wind stress and heat fluxes alone might predict a significant part of the circulation, but cannot predict the chaotic portion of the ocean's evolving circulation patterns. Observations with unprecedented accuracy and resolution of the global ocean surface are now being made by satellite-borne altimeters and AVHRR sensors. Up to three altimeters will be orbiting simultaneously for much of the next several years. The Naval Oceanographic Office's Altimetry Data Fusion Center (ADFC) is nearly ready to begin distributing processed data from these sensors to operational users in near-real time. Previous studies and demonstrations by NRL have shown that accurate nowcasts of much of the ocean's density and currents is possible given only an accurate estimate of sea surface height and sea surface temperature.

The challenge today is to produce more accurate altimeter heights by improving the synthetic geoid, correcting orbit error, and improving space/time interpolation. A skillful model, together with various correction/improvement techniques, provides the most accurate mean surface height field (used to generate the synthetic geoid) and will also be an accurate dynamic interpolator of the altimetry data which is only available along satellite groundtracks. Using statistical techniques (MODAS 2 synthetic data bases) and the global observations, ocean nowcasts of naval interest are possible without numerical models and were demonstrated in FY97, however using the numerical models to improve the accuracy of the sea surface height fields will greatly improve the skill of the nowcasts. Our objective is

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to develop and demonstrate the improved capabilities for ocean nowcast/forecast systems, focused on the Pacific basin using the 1/16 degree NLOM. These capabilities will be transitioned to FNMOC for operational Navy use.

APPROACH

Our approach is partly based on experience gained from a prior system and is determined by the characteristics of the most efficient and realistic ocean models most recently available, and by the types of observations available for real-time analysis. An evaluation of the previous system, which is a published book chapter, determined that the nowcast prediction skill was marginal overall, but that skill was high in some regions. The reduction in overall skill resulted from several identified factors, but the major error source was identified as a bias in the ECMWF winds which were used to force the model during the study. Our development strategy focuses on improvement of each of these factors.

The TOPEX/Poseidon, ERS-1, and ERS-2 altimeters presently provide measurements of the sea surface level to be augmented by the GEOSAT Follow-On and TOPEX Follow-On satellites. Two primary sources of error are the geoid and satellite orbit. The dynamically important surface topography is recovered by removal of the geoid from the sea level. Two methods will be combined to improve the geoid accuracy. An iterative technique will be applied where altimeter heights are assimilated into an ocean model over a one or two-year period on each iteration. A second method will determine corrections to a mean surface topography using a modification of the method pioneered by K. Kelly. In our application, a more general approach which uses ocean model basis functions will replace the prescribed functions she and others have used in studies of the Kuroshio, Gulf Stream, and Antarctic Circumpolar Current.

NRL has many years of experience developing and testing nowcast/forecast systems using operationally available data. This project would take the latest version of the NRL thermodynamic model for the Pacific and upgrade the earlier DART system. The assimilation scheme must be robust and meet the requirements developed in our first generation system of the North Pacific that was demonstrated in FY94. This would include altimetry assimilation, rubber sheeting and synthetic temperature and salinity profiles.

The altimeter heights will be assimilated using a combination of optimum interpolation, statistical inference, and nudging. However, the methods will depend upon the model chosen. Past experience with parameter optimization in a Gulf Stream regional system indicates that substantial improvements in performance can be obtained by empirically adjusting parameters used in the assimilation methods. More advanced methods of assimilation such as the adjoint of Kalman filtering techniques have not yet reached a state where they are practical alternatives. Presently, they show only small improvements over standard methods, but at very high cost.

The rubber sheeting technique, used in the previous system, produces a spatially correlated local remapping of the model fields to match the locations of fronts and eddies observed in satellite IR imagery. It is particularly effective in strong frontal regions where there are important features with space and time scales too small to be adequately sampled by the

altimeters. Work will also continue on the automatic detection and delineation of the fronts and eddies in IR imagery.

The possibility of assimilating tomographic travel times will be studied. The development of the tomographic processing and assimilation will be accomplished as part of the NRL effort in a funded NOPP project. The results of the effort will be added to our system and modified as needed.

WORK COMPLETED

1. 1/16 degree Pacific model spun up with climatological winds and simulations with operational winds have started (to be used for statistical inference data bases)
2. Synthetic data bases for Pacific basin are complete and ready for use with MODAS 2
3. First generation global synthetic geoid completed (currently being evaluated and transitioned to the ADFC at NAVOCEANO).

RESULTS

1. 1/16 degree model climatology compares favorably with other ocean climatologies including the 1/4 degree Levitus and the NRL(Carnes) MODAS climatology.
2. Methods to improve synthetic geoid using iterative method with NLOM are developed using 1/4 degree global model and will now be applied to the 1/16 degree Pacific model in order to calculate and improved mean sea surface.
3. Synthetic profiles generated from global sea surface height analysis compare very well with independent AXBTs in the Pacific basin.
4. Initial tests of embedded mixed layer model using a 1/8 degree Pacific NLOM show promise and will be tested further with the 1/16 degree model.

IMPACT/APPLICATIONS

The development of the eddy-resolving Pacific nowcast/forecast system is the first system of a global eddy-resolving capability by the year 2000. The techniques being developed in this system will also be used for planned capabilities using the 1/32 degree NLOM in the subtropical Atlantic and a 1/8 degree global system that will provide boundary conditions to the higher resolution basin-scale systems.

TRANSITIONS

The project will develop and evaluate individual models and components of the basin-scale system as well as the composite system and then transition to a coordinated 6.4 project (NO96.SPAWAR 6.4). The 6.4 project will make upgrades to a global circulation model and assimilation system which will be running operationally at FNMOC. The first component, soon to be delivered by the 6.4 project for operational use, is a 1/4° global thermodynamic OCEANS model forced by the Navy NOGAPS atmospheric model wind stress. Upgrades will include addition of altimeter data assimilation during FY98. The basin-scale system or subdomain system developed in this proposed project will be nested in the global model and transitioned to FNMOC

Specific plans for transition (from 6.2 to 6.4) are: (1) Complete development of and validate the basin-scale nowcast/forecast system including assimilation of operationally available data. (2) Develop method for coupling system to NRL global model. (3) Assist the COAMPS group in further development of coupled ocean-atmosphere models. Make our synthetic climatologies available and feed back our test results to them. (4) Automate the rubber sheeting technique (complete in later years). (5) Improve parameterization for combined optimum interpolation/statistical inference/nudging assimilation scheme.

RELATED PROJECTS

We will incorporate the work of several groups to make the operational system, including: (1) OCEANS model development by the Global 6.1 project and the 6.1 Low Latitude Western Boundary Currents, (2) Real-time altimeter data processing by the NAVO Altimeter Data Fusion Center, (3) Embedded mixed-layer model development for OCEANS model by the Forced Upper Ocean Dynamics project, (4) Layered model nesting by the NOMP Shipboard/Tactical project, (5) Tomography issues by the 6.2 NOPP project, (6) Issues related to providing deep-water boundary conditions for the California Current model by the 6.4 Global modeling project and for the East Asian Sea model (both Princeton models) by the 6.2 Coastal Modeling project, (7) Assimilation parameter optimization by the COAM, Univ of S. Miss (funded by ONR).

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